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published in
Schizophrenia Research
2018

DOI (link to publisher)
10.1016/j.schres.2017.04.034

document version
Publisher's PDF, also known as Version of record

Schizophrenia Research 192 (2018) 96–101

Contents lists available at ScienceDirect

Schizophrenia Research

journal homepage: www.elsevier.com/locate/schres

Social environments and interpersonal distance regulation in psychosis: A virtual reality study

Chris N.W. Geraets [a,*], Marije van Beilen [a], Roos Pot-Kolder [b,c], Jacqueline Counotte [b], Mark van der Gaag [b,c], Wim Veling [a,b,d]

[a] University of Groningen, University Medical Center Groningen, Department of Psychiatry, PO Box 30 001, 9700 RB Groningen, The Netherlands
[b] Parnassia Psychiatric Institute, Kiwistraat 43, 2552 DH The Hague, The Netherlands
[c] VU University, Department of Clinical Psychology, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
[d] Maastricht University, Department of Psychiatry and Neuropsychology, PO Box 616, 6200 MD Maastricht, The Netherlands

ARTICLE INFO

Article history:
Received 2 December 2016
Received in revised form 14 April 2017
Accepted 16 April 2017
Available online 23 April 2017

Keywords:
Interpersonal distance
Personal space
Psychosis
Social environment
Virtual reality

ABSTRACT

Background: Experimentally studying the influence of social environments on mental health and behavior is challenging, as social context is difficult to standardize in laboratory settings. Virtual Reality (VR) enables studying social interaction in terms of interpersonal distance in a more ecologically valid manner. Regulation of interpersonal distance may be abnormal in patients with psychotic disorders and influenced by environmental stress, symptoms or distress.
Aims: To investigate interpersonal distance in people with a psychotic disorder and at ultrahigh risk for psychosis (UHR) compared to siblings and controls in virtual social environments, and explore the relationship between clinical characteristics and interpersonal distance.
Methods: Nineteen UHR patients, 52 patients with psychotic disorders, 40 siblings of patients with a psychotic disorder and 47 controls were exposed to virtual cafés. In five virtual café visits, participants were exposed to different levels of social stress, in terms of crowdedness, ethnicity and hostility. Measures on interpersonal distance, distress and state paranoia were obtained. Baseline measures included trait paranoia, social anxiety, depressive, positive and negative symptoms.
Results: Interpersonal distance increased when social stressors were present in the environment. No difference in interpersonal distance regulation was found between the groups. Social anxiety and distress were positively associated with interpersonal distance in the total sample.
Conclusion: This VR paradigm indicates that interpersonal distance regulation in response to environmental social stressors is unaltered in people with psychosis or UHR. Environmental stress, social anxiety and distress trigger both people with and without psychosis to maintain larger interpersonal distances in social situations.

1. Introduction

Psychotic disorders often involve impaired social functioning (Couture et al., 2006; Van Beilen et al., 2003). Adequate social functioning includes keeping an appropriate physical distance to others. It is difficult to study a dynamic concept such as interpersonal distance, as laboratory settings do not represent real life social contexts and often lack interaction between the subject and environmental characteristics. Using Virtual Reality (VR), the current study investigated the influence of social environments on interpersonal distance in psychosis.

Personal space or interpersonal distance, is the distance we keep to people in our surroundings. Personal space is regulated dynamically and intrusion of personal space boundaries causes discomfort (Hayduk, 1978). Several factors influence which distance is desirable or appropriate at a certain moment. For example, when feeling threatened, people enlarge their distance to others (Hayduk, 1978). In contrast, when accompanied by familiar people, personal space boundaries become smaller (Hall, 1963; Nechamkin et al., 2003). Other factors influencing interpersonal distance are cultural norms, age, gender (Ozdemir, 2008) and psychopathology (Asada et al., 2016; Kim et al., 2009).

People with psychosis were shown to prefer larger distances than controls in dyadic paradigms, that is, relative to a single person or single stimulus (de la Asuncion et al., 2015; Deus and Jokić-Begić, 2006; Duke and Mullens, 1973; Schoretsanitis et al., 2015). Dyadic studies usually use tasks on paper or stop-distance tasks. In stop-distance tasks subjects are approached and have to indicate when they feel the approaching person gets so close that the subject starts to feel uncomfortable (Schoretsanitis et al., 2015).

* Corresponding author.
E-mail address: c.n.w.geraets@umcg.nl (C.N.W. Geraets).

http://dx.doi.org/10.1016/j.schres.2017.04.034
0920-9964/

In the last decade, dyadic interpersonal distance research has been extended with VR. Immersive VR experiments are more ecologically valid than pen and paper tasks but can still be controlled and replicated in a degree that is impossible in real life experiments (Blascovich et al., 2002). Healthy subjects showed a positive relation between subclinical paranoid ideation and interpersonal distance in a dyadic VR setting (Fornells-Ambrojo et al., 2016). Park and others (2009) observed a complex relation between interpersonal distance, facial affect and negative symptoms in patients with psychosis. Interpersonal distances were smaller when more negative symptoms were present, but only if avatars looked angry or neutral and not when looking happy. These findings suggest that interpersonal distance regulation may depend on multiple social and personal characteristics.

An unexplored aspect of interpersonal distance is the influence of social environments. Especially in patients with psychosis, the environment may be of importance for social functioning. Social stimuli in the surrounding which are meaningless to most people, can be threatening or over-arousing to people with psychotic disorders (Collip et al., 2011; Haralanova et al., 2012; Kapur, 2003) and may increase interpersonal distance as a form of safety behavior. Moreover, increased stress reactivity (Myin-Germeys and van Os, 2007) and cognitive biases are common in psychosis (Van der Gaag et al., 2013). Together, this could result in elevated distress levels or paranoia in response to social environments. Primary results of the current study showed that patients with psychosis and at ultrahigh risk for psychosis (UHR) were indeed more sensitive to virtual social environmental stress than controls (Veling et al., 2016). Higher levels of social environmental stressors were related to increased paranoia and psychological distress.

Abnormal interpersonal distances can cause problems in social interactions (Hall, 1966). When distances become larger it might be more difficult to see and interpret facial affect. Also, people could respond differently if someone does not follow the social norms of personal space, which can contribute to paranoia, misinterpretations and social isolation in psychosis. A safety and feasibility pilot study on social environmental VR designs by our research group unexpectedly found that, compared to controls, psychosis patients kept smaller rather than larger interpersonal distances in virtual social environments (Veling et al., 2014), but the sample was too small to draw conclusions.

In this study we investigated interpersonal distance regulation in response to social environments in people with different psychosis liability; patients with a psychotic disorder, individuals at UHR, siblings of patients and controls. Participants were exposed to virtual surroundings differing in social stress in terms of crowdedness, ethnicity and hostility. To explore mechanisms by which environmental stress might influence interpersonal distance, the relation with symptoms and mental states was examined.

We hypothesised that (a) interpersonal distance increases with the number of VR social stressors in the environment, (b) independent of psychosis liability, interpersonal distance is positively related to baseline levels of (subclinical) social anxiety and paranoia, and state paranoia and distress during VR experiments, (c) people with psychotic disorders and UHR keep larger interpersonal distances compared to healthy controls and siblings, and (d) there is an interaction between level of virtual social stressors and psychosis liability on interpersonal distance, that is, the effect of social stressors on interpersonal distance is larger in people with psychotic disorders and UHR than in siblings and controls.

2. Methods

2.1. Subjects

Four groups of participants aged 18–35 were enrolled: people with a psychotic disorder (psychosis), people with an UHR status (UHR), siblings of people with a psychotic disorder (siblings) and healthy controls (HC).

Psychosis participants were in treatment for first episode psychosis (unrelated to substance use or medical conditions), diagnosed in the preceding five years. The diagnosis was verified with a Schedules for Clinical Assessment in Neuropsychiatry (Wing et al., 1990) or Comprehensive Assessment of Symptoms and History interview (Andreasen et al., 1992). No cut off scores for positive or negative symptoms were used as an exclusion criteria for the psychosis group. UHR participants were help-seeking patients at outpatient departments of mental health care facilities, and were identified as being at risk for psychosis according to the Comprehensive Assessment of At-Risk Mental States criteria (Yung et al., 2005). Siblings and HC had no history of psychosis, nor did first degree relatives of HC. Exclusion criteria for all subjects were: IQ < 75, history of epilepsy and insufficient command of the Dutch language. Psychosis, UHR and siblings were recruited from five mental healthcare facilities. HC were recruited through advertisements at schools, dental offices and healthcare institutes.

Subjects signed informed consent preceding the study, and received a ten euro gift card for participating. The study was approved by the medical ethical committee of Leiden University Medical Center and conducted according to the principles of the Declaration of Helsinki (October 2008).

2.2. Study design

The study has a crossover between group design. Participants completed questionnaires and subsequently five experimental blocks consisting of a VR experiment, followed immediately by a distress measure and questionnaire.

2.3. VR environment

Experiments took place in a VR 3D café with a terrace covering an area of 181 m^2 (Fig. 1), created by CleVR with Vizard software. The café was presented through a head mounted display (HMD, Sony HMZ-T1) with a resolution of 1280 × 720 per eye and 51.6 diagonal field of view, integrated headphones and a built-in 3DOF head tracker. Participants moved by operating a joystick (Logitech F3 Gamepad). Avatars were standing or sitting at tables in the VR café. When participants approached avatars, some avatars would look their way briefly, others remained interacting and drinking. Participants heard random café background noises through the headphones.

The social stressors present in the café differed in each experiment. This was accomplished by manipulating three variables: crowdedness, facial expression and ethnicity, see Table 1. The ethnicity of minimal 80% of the avatars was similar or different (white Caucasian or North-African) to the ethnic appearance of the participant. The facial expression of the avatars was neutral or hostile. During the neutral condition avatars continuously looked neutral at each other and the participant. In the hostile condition hostile looks (duration of five seconds) were interspersed with neutral looks.

2.4. Procedure

Subjects were instructed to explore the virtual environment with the avatars, and perform a task to ensure that the VR café was explored. Five avatars had a number on their shirt, ranging from 0 to 99. Participants had to find the avatar with the highest number, and remember that avatar's number and gender. Each VR exposure lasted four minutes; between experimental blocks was a five-minute break. The order of exposure was randomized, with exception of the last experiment, when a minimal of two stressors was always present.

2.5. Measures

Baseline measures included demographic variables (see Table 2), the Community Assessment of Psychic Experiences (Konings et al., 2006),

Fig. 1. 2D Screenshots of avatars in the VR café.

the Green Paranoid Thought Scale (Green et al., 2008) and the Social Interaction Anxiety Scale (Mattick and Clarke, 1998).

During VR exposure, interpersonal distance (IPD) was measured automatically by the VR software. The distance was measured in millimeters from the center of the avatar's head to the front of the participant's head. The software calculated the average distance between the participant and each avatar within a radius of two meters of the participant at a rate of 10 Hz. The radius criterion of two meter was chosen based on previous VR research (Park et al., 2009) and the social distance zone by Hall (1966) which describes the distance people generally keep to strangers in public places and casual conversations. The mean IPD was calculated per experiment for all avatars and avatars with numbered shirts only to check whether the task influenced interpersonal distances.

Furthermore, positions of participants were registered at 10 Hz to check whether subjects explored the café. Exploration index 1 was defined as the average distance between all registered positions. This is an indication of the distance covered by subjects; the standard deviation (exploration index 2) hereof reflects the degree to which participants were at different positions in the café. Means were computed per group.

Peak distress and state paranoia were measured directly after each VR exposure. Peak distress was assessed by asking the participant to think back to the moment at which they experienced the highest distress during the exposure and rate this distress on a scale from 0 'no stress at all' to 100 'most stressful imaginable'. With the State Social Paranoia Scale (SSPS; Freeman et al., 2007) paranoid thinking about the avatars was assessed per experiment. The SSPS is a 20-item questionnaire, with 10 items assessing persecutory thoughts (e.g. "someone had bad intentions towards me"), and 10 items measuring positive and neutral thoughts on a 5-point-scale.

2.6. Data analysis

The sample size ($n = 50$ per group) was determined by the primary outcome measures to detect a small to medium effect, see Veling et al. (2016). To assure that this sample size was sufficient for detecting differences in interpersonal distance the online software GLIMMPSE was used for power analysis (Guo et al., 2013). The analysis was performed accounting for a potential drop-out rate of 20% ($n = 40$ per group). Based on a VR pilot study, the standard deviation was estimated to be 6 cm at each time-point (Veling et al., 2014). The significance level was set at 0.05, and the correlation between the repeated measures was assumed to be 0.3. Under these assumptions the statistical power to detect a difference of 5 cm was 0.99. As the VR pilot study found differences of this magnitude in interpersonal distance between patients and controls and the majority of previous studies reported much larger differences of 20 to 60 cm (e.g. de la Asuncion et al., 2015; Deus and Jokić-Begić, 2006; Holt et al., 2015), the sample size of 40 participants per group was considered sufficient.

Data were analyzed with IBM SPSS Statistics 22. Significance was accepted at 0.05. Groups were compared on baseline measures and exploration indices with a chi-squared test, ANOVA, or Kruskal–Wallis test (non-parametric).

IPD outcome measures were analyzed with linear mixed models (LMM) (MIXED software function). First, mean IPD of all avatars and numbered avatars were analyzed on the factors group (Psychosis, UHR, Siblings and HC), experimental condition (A, B, C, D and E) and the interaction group X experimental condition. Second, explorative analyses on the relation between IPD and clinical characteristics as well as mental states during VR exposure were performed. The method of estimation used was restricted maximum likelihood. Experimental condition was treated as the repeated factor to control for the

Table 1
Overview of the stressors present in the virtual café during the experiments.

Experimental Condition	Social stressors		
	Crowdedness	Hostility	Own ethnicity
A	6 Avatars	Neutral	80%
B	40 Avatars	Neutral	80%
C	40 Avatars	Neutral	20%
D	40 Avatars	Hostile	80%
E	40 Avatars	Hostile	20%

Table 2
Baseline sociodemographic and (sub-) clinical characteristics.

	HC		Siblings		UHR		Psychosis		
	$n = 47$		$n = 40$		$n = 19$		$n = 50$		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*p*
Age	24.3	4.3	26.5	4.8	24.3	4.4	26.0	4.6	0.07
Male (%)	46.8		55.0		36.8		80.0		0.001
Dutch origin (%)	72.3		72.5		73.7		52.0		0.09
Level of education (%):									
Vocational or lower	25.5		27.5		36.8		52.0		
Selective secondary	19.1		7.5		26.3		20.0		0.002
Higher	55.3		65.0		36.8		28.0		
CAPE									
Positive symptoms	24.2	4.7	23.7	3.1	32.3	7.2	31.0	8.7	<0.001
Negative symptoms	21.3	4.7	21.3	3.7	32.9	7.8	27.1	6.5	<0.001
Depressive symptoms	12.4	2.8	12.4	2.2	20.5	4.7	14.7	3.4	<0.001
GPTS									
Social reference	20.5	7.1	19.6	5.0	39.1	13.6	28.8	14.6	<0.001
Persecution	16.8	2.0	16.6	1.9	30.9	14.1	25.9	14.3	<0.001
Paranoia total	37.3	8.9	36.2	6.1	70.0	27.0	54.7	28.5	<0.001
SIAS									
Social anxiety	16.7	12.1	15.3	10.5	39.4	19.8	28.3	15.4	<0.001
Exploration index 1	7.0	0.5	6.9	0.4	6.9	0.4	6.7	0.6	0.08
Exploration index 2	4.6	0.3	4.6	0.3	4.6	0.2	4.5	0.4	0.27

Note: CAPE; Community Assessment of Psychic Experiences, GPTS; Green Paranoid Thought Scale, SIAS; Social Interaction Anxiety Scale.

dependency of measurements. Model and covariance structure selection took place by comparison of goodness of fit with the Bayesian's Information Criterion. Gender and age were added as covariates to all models.

3. Results

3.1. Participant characteristics

156 participants were included for data analyses. Inclusion criteria were met by 170 people. Two participants were excluded because of missing baseline data. Twelve were excluded because less than two experiments were completed correctly due to cybersickness ($n = 10$) and failures in the experimental set-up ($n = 2$). Baseline characteristics and exploration indices are shown in Table 2. Exploration indices did not differ between groups, indicating that people covered a similar area of the café.

3.2. Interpersonal distance

The average IPD per experimental condition are shown in Table 3 and Fig. 2. The minimum measured IPD was 1.09 and the maximum 1.84 m. The LMM analysis on IPD relative to all surrounding avatars showed a significant main effect of experimental condition on IPD ($F(4144) = 3.02$, $p = 0.02$), no significant effect of group ($F(3149) = 2.25$, $p = 0.08$) and no significant interaction between experimental condition and group. Post-hoc pairwise comparisons (Bonferroni corrected for 20 tests) indicated that adding social stressors to the surrounding elicited an increase in IPD. People kept more distance to others relative to environment A (no stressors) in environment B ($p = 0.03$), C ($p = 0.06$; marginally significant), D ($p = 0.03$) and E ($p = 0.01$).

For IPD to numbered avatars, which participants had to approach during the experiments, a marginal non-significant main effect of experimental condition was found ($F(4560) = 2.17$, $p = 0.07$). No significant effect of group or the interaction of group and experimental condition was found.

3.3. Relation with clinical variables

The relation between IPD and clinical characteristics was explored across the entire sample. A significant positive association was found between IPD and peak distress ($b = 0.033 \pm 0.012$ cm, $t(147) = 2.14$, $p = 0.007$). In addition, trait social anxiety was related to IPD ($b = 0.050 \pm 0.023$ cm, $t(346) = 2.60$, $p = 0.03$), higher scores resulted in a larger IPD. When both baseline social anxiety and peak distress were entered in a single model, the goodness of fit did not improve. No relationship was found with state paranoia or the following baseline measures: paranoia, positive, negative or depressive symptoms.

4. Discussion

4.1. Main findings

Larger distances were kept to others in the café when one or more stressors (i.e. crowdedness, hostility and ethnic minority) were present compared to no stressors. Interpersonal distance was positively related to the level of reported distress, and individuals with higher pre-existent levels of social anxiety kept larger distances to others, regardless of psychosis liability. All psychosis liability groups responded similarly to different social environments; no difference in regulation of interpersonal distance was found between people with a psychotic disorder, UHR, siblings or healthy controls.

Independent of psychosis liability, crowdedness did influence interpersonal distances to (virtual) people. When 40 avatars were present in the VR café people kept larger distances to others than when only six avatars were present. This supports the notion that social parameters can influence interpersonal distance. The presence of others may have elicited arousal or distress, which may have led to larger personal space preferences as a form of subtle safety behavior. When the crowd was hostile or the majority had another ethnic appearance this did not further increase interpersonal distance. In contrast, a VR study by Dotsch and Wigboldus (2008) found native Dutch people to keep larger distances to North African avatars than white Caucasian. Possibly the maximum effect of social environmental stress was already achieved when 40 avatars were present in our study, due to the task or limited area of the VR environment, herewith covering a potential effect of ethnicity and hostility.

Our data suggest that interpersonal distance might be affected by more general states, such as psychological distress, that are common but not specific for psychosis. When subjects reported the café visit as being more distressing, this was reflected in a small but significant behavioral change, by keeping more distance to avatars. This is consistent with theory stating the primary function of personal space is to protect from over-arousal and feelings of discomfort (Delevoye-Turrell et al., 2011; Hayduk, 1978). No association was found between paranoid thoughts about the avatars during café visits and interpersonal distance. As for baseline characteristics, only social anxiety was related to interpersonal distance, which is congruent with previous research in socially anxious people showing enlarged personal boundaries (Rinck et al., 2010; Wieser et al., 2010). Whereas previous results on the relation between interpersonal distance and positive and negative symptoms have been inconsistent, this study provides new insights by focusing on different states and symptoms such as distress and social anxiety.

The finding of similar interpersonal distance regulation in people with different levels of psychosis liability was unexpected and contrary to the hypotheses. We think that our finding of no differences between groups represents a true negative finding. Whereas the sample size was

Table 3
IPD group means and standard deviations per experimental condition.

		A No stressors		B Crowded		C Crowded + ethnic minority		D Crowded + hostile		E Crowded + hostile + ethnic minority	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
IPD (cm) kept to all avatars	HC	143.8	9.7	146.7	5.8	145.4	5.5	144.0	6.1	145.4	5.1
	Siblings	142.4	10.0	145.5	5.6	146.0	5.1	146.3	6.3	146.4	6.4
	UHR	143.4	7.3	144.3	4.5	143.8	5.0	145.6	6.2	145.4	3.8
	Psychosis	144.1	11.9	147.5	7.5	148.0	6.4	148.0	6.8	148.2	6.5
	Total	143.4	10.2	146.3	6.2	146.1	5.8	146.0	6.5	146.4	6.0
IPD (cm) kept to numbered avatars	HC	144.3	10.1	145.1	13.5	145.8	11.1	146.1	13.5	141.9	11.7
	Siblings	142.4	9.9	144.2	9.9	144.8	9.3	146.4	13.5	145.6	12.8
	UHR	144.2	9.9	142.2	10.4	141.1	12.7	148.8	10.9	147.3	10.4
	Psychosis	143.2	11.9	145.6	12.4	146.8	11.8	146.9	16.1	147.7	12.0
	Total	143.5	10.5	144.6	12.0	145.1	11.3	146.8	13.9	145.2	12.1

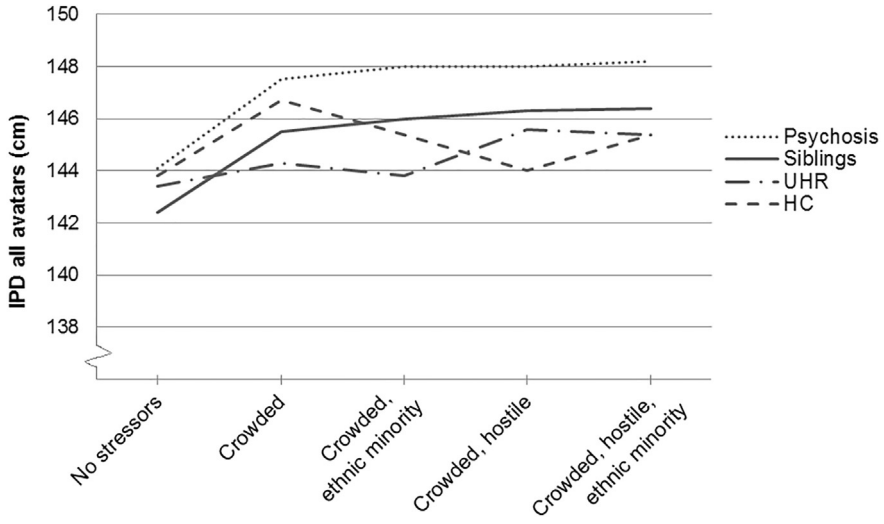

Fig. 2. Mean IPD relative to all avatars in the VR café.

rather large for an interpersonal distance study, the differences between the groups were very small. Within an experimental condition the largest observed difference between groups was ~4 cm. This is in contrast with previous research using an explicit stop-distance task, which found differences in interpersonal distance as large as ~60 cm between healthy controls and psychosis patients (Deus and Jokić-Begić, 2006). The differences found in dyadic studies are quite extreme, and raises the question whether these results generalize to real life situations.

Whereas environments with high levels of social stressors caused relatively more feelings of distress in people with higher psychosis liability (Veling et al., 2016) this did not lead to significantly increased distances in the psychosis or UHR group. Also, baseline social anxiety differed between groups but was not reflected in group differences in interpersonal distance. Although these results seem conflicting, it is explained by the fact that distress and social anxiety only *partially* explained interpersonal distance, and because people are quite heterogeneous.

4.2. Dyadic vs. social environmental VR paradigms

We do not have an unequivocal explanation for the difference in findings between dyadic paradigms and the present social environmental VR paradigm. However, two differences between the paradigms might contribute to the discrepancy in results.

First, in classic paradigms (as stop-distance tasks and questionnaires), subjects are asked explicitly to indicate their interpersonal distance. This requires the subject to be aware of his or her personal space preferences in a particular situation. In VR, interpersonal distance is measured implicitly, without the participant knowing that it is measured or of interest. The process of explicitly considering at which interpersonal distance you feel comfortable, may more strongly reflect level of paranoia or problems with social cognition than an implicit VR measure. Differences between implicit and explicit processing of social cues have been observed before in patients with psychosis. Whereas explicit processing was impaired, implicit processing was preserved (Linden et al., 2010).

Second, dyadic research is mostly performed in laboratory settings, which are deprived of (social) stimuli. Whereas previous VR studies already used more natural surroundings, only a single avatar was present in these VR worlds (Fornells-Ambrojo et al., 2016; Kim et al., 2009). Interpersonal distance in the present paradigm was measured in a VR café which six to 40 (virtual) people were visiting, forming a complex social environment. Furthermore, avatars in the café reacted on the participant, making this VR setting socially dynamic and interactive. In such complex environments many stimuli are present, causing attention to be divided, which might reduce the tendency of individuals with psychosis to keep more distance.

4.3. Limitations

Experiments were done in a single virtual setting therefore generalizability to other VR and real environments remains to be established. Previous research demonstrated generalizability of behavior in VR to real life (Eichenberg and Wolters, 2012) as well as the use of similar social norms during interactions in VR and real life (Yee et al., 2007). The sample size of the UHR group was relatively small ($n = 19$) in this study. Ten participants dropped out because of cybersickness, a side effect of VR that manifests in symptoms such as dizziness and nausea. Most dropouts ($n = 6$) occurred in the largest group (healthy controls) therefore we do not expect that this influenced results. In this study symptoms may have been less severe compared to other studies. The symptom level of the psychosis patients was similar and in some dimensions lower (depressive and social reference dimension) than the symptom level of UHR. Possibly this reflects that UHR have high comorbidity rates (Fusar-Poli et al., 2014; Rietdijk et al., 2013). Moreover it shows that the patients of this study had a relatively low symptom severity. Future studies could add patients with a broader spectrum of symptom severity to verify whether the results of this study generalize. Finally, people from different cultures are known to have different interpersonal distance preferences. We could not correct for culture reliably because participants of non-Dutch origin had been living in the Netherlands for several years. As a result the cultural norms of these participants were probably a mix of the culture of origin and the Dutch.

4.4. Conclusion and implications

Our findings suggest that the regulation of interpersonal distance is not affected in patients with UHR or psychosis with respect to people in the general surrounding. Interpersonal distance does appear to be related to emotional states or symptoms non-specific for psychosis such as feelings of distress and social anxiety.

Whereas previous research has recommended to target interpersonal distance regulation in social-skills training and psychoeducation (e.g. Deus and Jokić-Begić, 2006; Nechamkin et al., 2003), we did not find evidence to support this recommendation. This study did provide preliminary evidence that social environmental factors might be more important in social behavior research than is currently thought. Due to methodological issues it has long been impossible to take the

environment into account experimentally; VR seems to be a suitable tool to overcome these problems.

Author's contributions

Geraets and van Beilen wrote the first draft of the manuscript. Geraets managed the literature searches and statistical analysis. Veling, and Van der Gaag supervised and designed the study. Pot-Kolder and Counotte contributed with acquisition, administrative and technical support. All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare no conflicts of interest.

Funding and support

This study was supported by a Veni laureate to Veling from the Netherlands Organization for Health Research and Development (916.12.013), and by EU-GEI (HEALTH-F2-2009-241909).

Acknowledgements

None.

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